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**Application of Zone Logic and Outfit
Planning Concepts to Overhaul, Mod-
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Ships**

**U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER**

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**APPLICATION OF ZONE LOGIC
AND OUTFIT PLANNING CONCEPTS
TO OVERHAUL, MODERNIZATION,
AND REPAIR OF U. S. NAVY SHIPS**

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FEBRUARY 1985**

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ABSTRACT

This paper presents the experience of Puget Sound Naval Shipyard in applying zone logic and outfit planning concepts to the overhaul, modernization, and repair of an aircraft carrier, three cruisers, and a submarine. Procedures were developed to involve design, production, testing, and material personnel in the overhaul process from preplanning through completion of the production phase, with the resulting synergism and open communication. The systems approach was replaced with zone by stage sequenced work packaging with as much work as possible done off the ship. Computer Aided Design (CAD) and photogrammetry were applied to enhance preplanning and off-ship work.

Puget Sound Naval Shipyard's application of zone logic is drawn from the research managed by the Maritime Administration's National Shipbuilding Research Program which has introduced the highly successful scientific shipbuilding systems developed in Japan. In brief, this concept represents a shift in logic from system to zone orientation.

INTRODUCTION

Historically, all outfitting work in naval shipyards has been planned, scheduled, executed, and tested on a system by system basis. This method has developed for several valid reasons which include:

- Cost estimating and accounting
- Material estimating
- Ship operation and identification of problem areas
- System testing

While this method is acceptable and necessary for some shipyard functions, it is recognized that when repair work is actually accomplished it is not done solely on a system by system basis. Examination of any ship repair effort will show that work accomplishment is based on several criteria, one of which is the functional system. Other considerations must include:

- Physical location of work
- Manpower requirements
- Other work required in the same location
- Similar work required in other areas
- Availability of material

These parameters are currently being considered and resolved by trade general foremen, with decisions made on a trade by trade basis when the work is actually started. Typically, the general foremen are faced with making these day to day decisions without knowledge or understanding of the overall plan for completion of the overhaul. This often causes items to be installed in an improper sequence which results in unnecessary rework.

Additionally, manufacturing and installation of numerous outfitting components have traditionally been postponed until the hull is available to the trades to determine their construction requirements. This process has resulted in relegating outfitting to a successor function completely dependent on hull constraints, with the natural effect of requiring peak manning and confined outfitting schedules.

Through the application of system oriented logic to actual work accomplishment, there is no allowance for an

objective, analytical examination of the best possible way to perform work, nor does it provide a method of feedback to increase the corporate knowledge of the shipyard. With the various systems being considered separately, trades often occupy space and compete for access simultaneously which minimizes the effect of production scheduling and control, and creates strained channels of communication.

In looking at how outfitting work is actually performed, it is found that products are produced by procuring and/or manufacturing parts and joining them together to create subassemblies. These subassemblies are progressively combined to produce a completed operational product. It becomes clear that the ideal way to subdivide ship repair and overhaul work is to focus on the needed parts, or interim products, that pre-occupy the worker. Zone outfitting logic provides a scheme by which *work* is subdivided with interim products as the focal point.

Outfit planning addresses all outfitting components within a defined 3-dimensional space, and frees outfitting as much as possible from hull dependence and ship systems control. This provides the basis for grouping work into classes or problems so that common solutions can be applied regardless of product configuration and location, and planning installations in a logical sequence. The result of this scheme is that it permits most outfitting work to be accomplished earlier, and away from the ship to where it is safer, cleaner, and resources can be delivered to the worksite more economically. Overhaul durations can be reduced because of simultaneous accomplishment and coordination of outfitting and hull work which will minimize total shipboard construction time.

A zone is any subdivision of the planned work which best serves for

organizing information needed to support outfitting at a particular stage of an overhaul. A zone might be a compartment or a portion of a compartment; it could include an entire superstructure or a component subassembly. The principle aspect of a zone is that it represents a means of dividing a ship's overhaul package into manageable, trackable blocks. Zone outfitting features three basic stages: on-unit, on-block, and on-board, coordinated by the "master bill of erection sequence."

On-Unit

On-unit outfitting is the assembly of an interim product consisting of manufactured and purchased equipment (components). It includes all but a final coat of paint. A unit is composed exclusively of outfitting materials (pumps, motors, mechanical and electrical interfaces, and a common foundation including false floor ribbing, etc.). The on-unit outfit planning is separate from the main hull structure. Units can be categorized as (a) functional, (b) geographical, or (c) combination.

Functional units consist mainly of components necessary for the operation of something, e.g., a heat exchanger assembly. It is generally associated with one system (potable water and freshwater units, water distilling unit, F. O. purifier unit, refrigeration plant unit, etc.).

Geographical units provide passage(s) for systems. Such units are assembled together to insure that they will fit onboard (pipe, HVAC, or wireway passage(s) on deck unit, accommodation unit, engine room unit, etc.).

Combination units include more than one system built together and lifted to installation site (pipe/HVAC/wireway/machinery/associated foundations, grating/false floor attachments, handrails, etc.).

On-unit outfitting should be given the highest priority even though there is some impact on hull construction progress because assembly is performed in shops which provide ideal climate, lighting, and access. Shop work increases the opportunity for improved safety and higher productivity. Outfitting on-unit has less impact on the progress of hull structure as opposed to on-block outfitting.

On-Block

On-block outfitting is the installation of outfit components, or even a unit, onto a hull structural assembly or "block" prior to its erection. It is the next best alternative to outfitting on-unit. It includes all painting except a final coat and that paint omitted to anticipate welding of butts and seams. On-block outfitting requires coordination between hull, mechanical, ventilation, and electrical systems supported by material (supply), planning and estimating, and scheduling. A "master bill of erection sequence," developed by engineering, production, planning and estimating, and supply, is controlled by scheduling (via work order task assignment). This identifies the sequential road map in which systems are installed. Engineering lists systems and components to be involved on-block and provides the work package; production assists in the design planning stage designating the construction envelope and supports engineering on preferred design applications; planning and estimating defines the work packages by crafts and sequences the construction flow by landing dates; and material (supply) has the integral task of coordinating the material flow based on the "master bill of erection sequence" and only stages the identified materials required to support production flow.

On-Board

On-board outfitting includes, and ideally should be limited to, the connection of units and/or outfitted

blocks, final painting, and test and trials. It necessarily includes some installation of outfit components, in a hull at a building position or outfitting pier, which cannot be productively incorporated "on-unit" or "on-block."

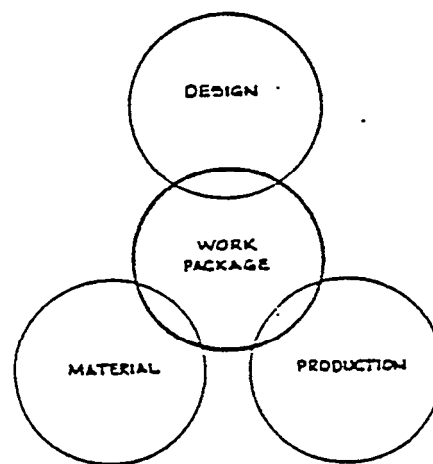


Figure 1

The work package acts as a common link to integrate work requirements.

One method used to organize information to support outfit planning is the work package concept. This is a conceptual approach that allows information from design, material, and production to integrate so that the various shipyard departments have a common understanding of how the ship will be overhauled. A work package is the common link to communicate a "build strategy" so that a definite increment of work with all located resources needed to produce a defined interim product is identified. A work package is also a definition of components of the various functional systems in a particular zone at a specified time of repair. This concept is extremely beneficial for staging material for delivery to a work-site.

Preoutfitting should not be confused with zone outfitting. Preoutfitting is usually planned by allocating resources to activities associated with ships'

systems in related large structural sections. Access is improved over conventional outfitting but components are still installed on a systems basis with great dependence on hull availability. Trades still compete for time and space, using unchanged methods, and material flow to the worksite is not optimized. Savings in total mandays and overall building period are limited because the only real difference between preoutfitting and conventional outfitting is where the work takes place. Preoutfitting of a very large structural assembly can be equivalent to outfitting a small ship of equal tonnage by conventional methods. Zone outfitting takes the additional step of freeing outfitting from hull dependence and systems control.

Puget Sound Naval Shipyard began its experiment with outfit planning by sponsoring two-day training seminars to all shipyard upper and middle level managers in May of 1982 and January of 1983. These seminars provided the necessary background to gain the shipyard-wide support needed to successfully carry out test cases for outfit planning. In February of 1983, while understanding that zone outfitting logic applied to new construction, the shipyard Planning Officer and Production Officer (with the support of the Shipyard Commander) called for the establishment of an Outfit Planning Group to determine if and how zone outfitting logic might be applied to the type of repair/overhaul work accomplished at Puget Sound Naval Shipyard.

OUTFIT PLANNING GROUP

Most shipyards that have adopted zone logic have completely restructured their organizations to reflect the concept. Since this was an exploratory project for Puget Sound Naval Shipyard, and because of its potential far reaching impact on the methods and procedures used within the shipyard, it was determined that an Outfit Planning Group with

representation from all shipyard departments was necessary to ensure total evaluation. This type of approach gave the shipyard the best opportunity to assure familiarity with all problems and solutions, and gets all departments involved in the planning and sequencing of all operations from issue of planning documents through completed installation testing.

The Outfit Planning Group formed at Puget Sound Naval Shipyard consisted of representation from the following departments:

- Combat Systems
- Design
- Overhaul Superintendent
- Planning and Estimating
- Plant Engineering
- Production
- Progress
- Scheduling
- SUPPLY
- Test Engineering

With this cross section of ship repair departments, the integration of outfit planning to ship repair received overall review to assure organizational coordination and agreement. The Outfit Planning Group became the forum by which the technical requirements and practical applications are integrated to develop a common "build strategy."

As shown in Figure 2, a core group evolved which had more direct involvement in the daily function of accomplishing repair work, and was in an optimum position to analyze the affects of zone logic on individual and shipyard methods. The core group interacted among themselves, and within their own departments, to examine, resolve, and promote the application of new approaches developed from zone logic. Corroboration with the periphery departments is maintained when their specialties are involved and at periodic verification reviews. This process proved to be reliable by allowing the smaller group to efficiently operate

and still sustain total shipyard involvement. This forum is at all times tasked to be creative in the analysis of the technical and manufacturing processes to stimulate smarter approaches during the project evolution.

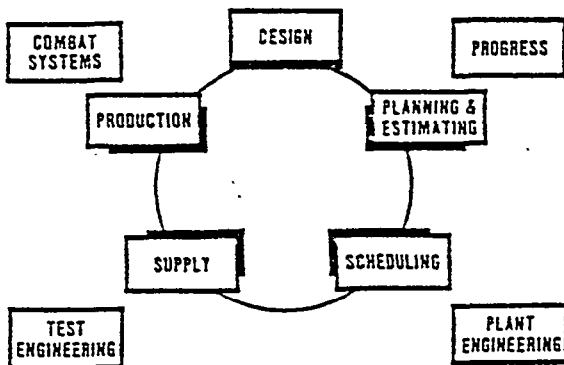


Figure 2
Outfit Planning Group

The Outfit Planning Group uses a unique dual management posture which reflects the work emphasis shift from the planning phase to the production execution phase, and the direct link between design requirements and production applications. These two leadership positions are represented by the Design Division (chairman) and Production Department (zone manager). influence of design requirements paramount in the early planning process, the chairman leads the Outfit Planning Group's efforts in defining work zone parameters. When the work is identified, the zone manager then takes the lead to direct the group's sequencing to reflect production needs. During the transition period between defining and sequencing, both work together to adjudicate the exchange of information between the various departments such that a fully integrated, zone oriented build strategy is proceeding. With zone logic in mind, the chairman is responsible for providing production with a sequenced work package, and the zone manager is responsible for executing the work package. Both are responsible for

assuring all the requirements and methods are coordinated and supported.

In order for the Outfit Planning Group to assimilate and associate all the information to implement zone logic concepts, a process framework was prepared to operate with. The following procedure organizes all the input related to the project and generates the master bill of erection sequence.

- Systems drawing preparation
- Composite drawing preparation
- Composite/system drawing analysis
- Work package identification
- Work package sequence
- Work package instruction

System Drawing Preparation. In accordance with current policy, traditional systems drawings are prepared and provided to the installing activity.

Composite Drawing Preparation. Using the data from the various systems drawings, a composite drawing is prepared to delineate all components to be installed within the defined zone boundaries, and existing shipboard components to be interfaced. Depending upon the complexity of the systems in the zone, the composite drawing will consist of plan views at various levels, and elevation views of particularly congested areas. This drawing provides a means to identify and correct potential interference items while still in the planning phase. More importantly, it is used as a tool by the Outfit Planning Group to trunk systems for the simplest fabrication and installation sequence.

Composite/System Drawing Analysis. The Outfit Planning Group performs a detailed analysis of the drawings to form an overall profile of the task. The analysis includes such items as:

- System requirements
- Trade involvement
- Material requirements
- Testing
- Facility impact
- Certification requirements

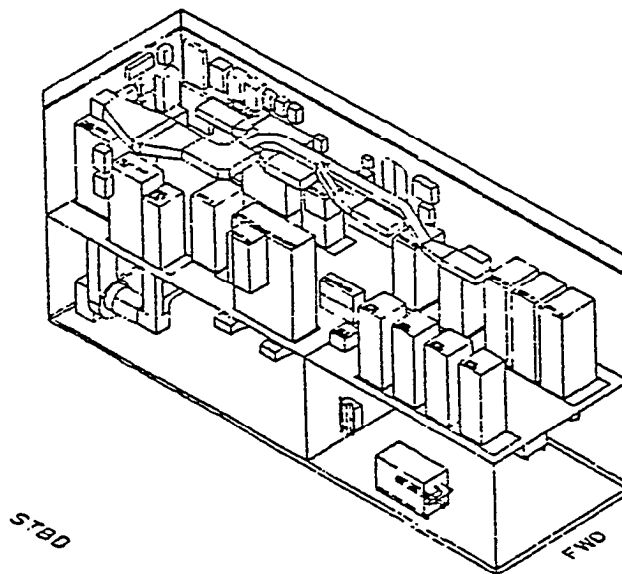


Figure 3
CAD composite depicting layering of equipment
and air conditioning within hull block.

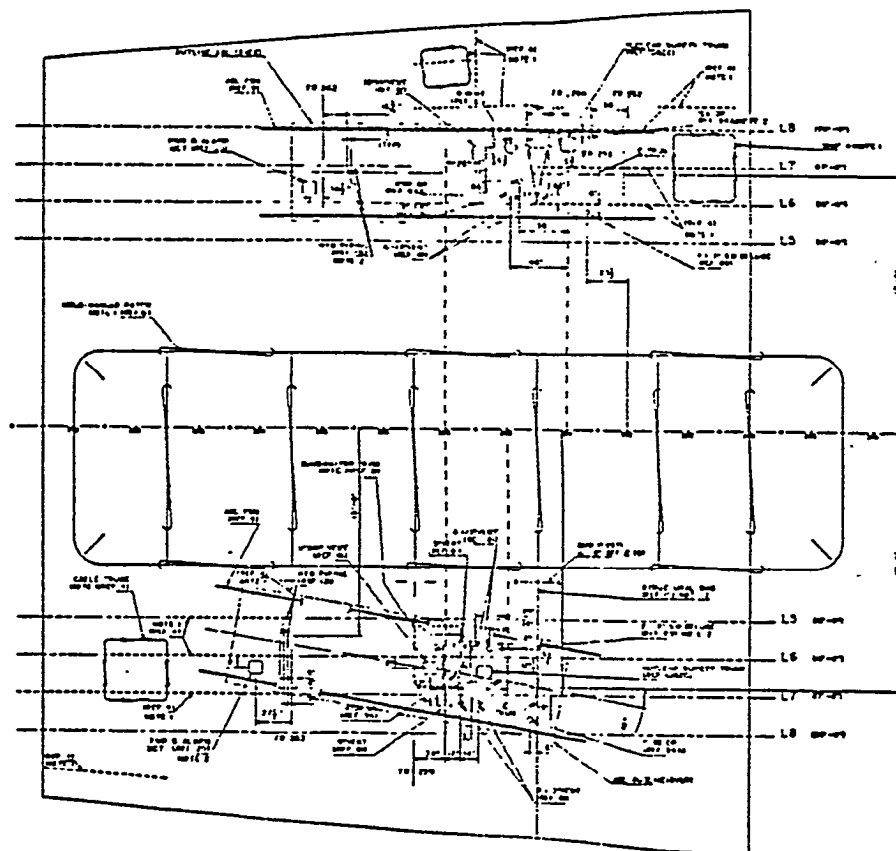
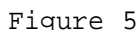


Figure 4
Composite view identifying common work procedure
for onboard site preparation.

modate decisions and commitments reached to form a final work package definition.

Work Package Sequence. The Outfit Planning Group arranges the work packages into a logical flow of work which represents the project build strategy. While this function is separate from work package identification, it is an integral element of the iterative decision making process to arrive at a final work package.



The work package diagram outlines the agreed to build strategy. Each work package is supported by an instruction.

Work Package Instruction. Once the work packages are identified and sequenced, the Outfit Planning Group prepares an instruction for each work package. This instruction is a synopsis of the work required to accomplish the work package and includes such information as:

- Work description
- Key shop
- Job order and key op
- Needed resources
- Highlighted sketch

These sheets are assembled into a book, and issued to the zone manager and involved trade foremen to be used as a tool to manage the project resources, aid the waterfront decision making process, and measure project progress.

CASE NO. 1: USS RANGER (CV 61)

The complex overhaul of the aircraft carrier USS Ranger (CV 61) provided the first opportunity for Puget Sound Naval Shipyard to determine how zone outfitting concepts could be adopted. Two shipalt packages were targeted for analysis. The areas selected furnished excellent opportunities to examine a good mix of systems work in two typical, but divergent types of overhaul tasks. The first task involved the construction and installation of a new deckhouse which closely resembles new construction processes (on-unit and on-block); while the second task accomplished complete reoutfitting of an existing space which represents typical overhaul work (on-board).

In order to concentrate on zone logic concept application and provide reasonable data for evaluation, the Outfit Planning Group limited it's focus to the specific compartments involved, and did not attempt to sequence work once a

system exited the defined zone. On the other hand, any non-related system "passing through" the zone was included in the build strategy.

With all the design, planning, and production work being accomplished at Puget Sound Naval Shipyard, the opportunity to open cross communication between the various departments was taken. Production Department concerns and needs were expressed to the design division so that documents could be enhanced to aid production methods. At the same time, design requirements were being explained to production personnel to aid their understanding of the projects. In a few cases, production personnel were loaned to the Design Division to prepare the drawings which were to be used for these tasks.

When the projects were ready for production to begin, a meeting of all involved trades was called to explain the build strategy. General foremen, foremen, and mechanics were represented so that all parties would have the same understanding of how work was to be accomplished. Each was also encouraged to provide input that would improve work sequencing analysis methods for future work.

Zone 1: Close-In Weapon System Deckhouse

This project consisted of fabricating, outfitting, and attaching a new 24'x26'x8'26-ton deckhouse to the out-board side of the existing island to accommodate a new defensive weapon suite. It required the coordination and sequencing of 14 various systems, and integrating these systems with the hull block construction. Preparation of the shipboard site was an additional major element to be incorporated into the build strategy.

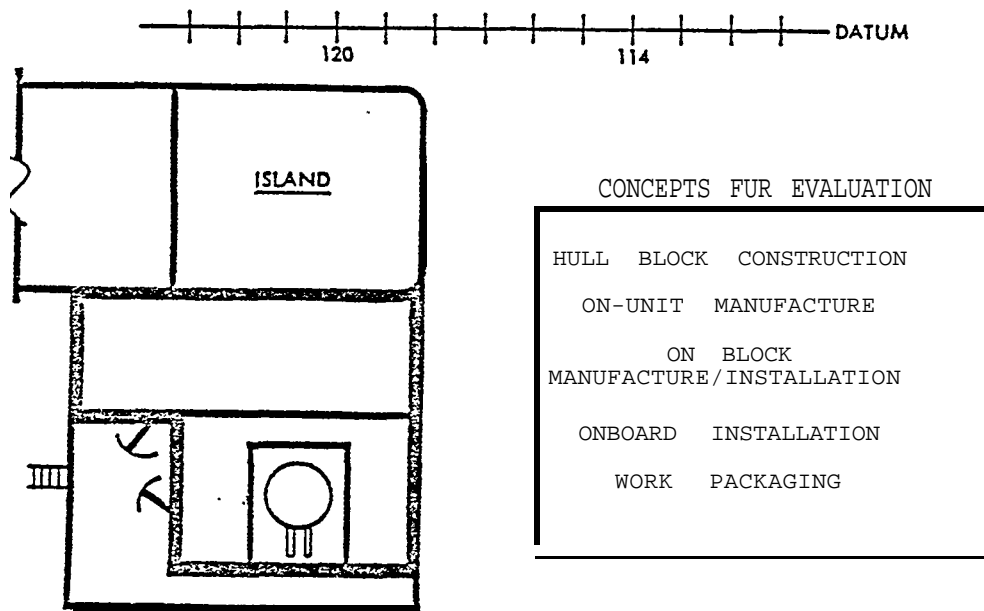


Figure 6
USS Ranger Close-In Weapon System

Through the use of the composite drawing, the hull block/outfitting interface areas were identified and incorporated in the structural construction phase of the deckhouse to support subsequent outfitting installations. All system penetrations and underdeck foundation stiffening in the new structure were detailed on the structural prefabrication drawing so that they could be included during the initial construction of the deckhouse. This process allowed for accomplishing common work procedures regardless of the particular system and independent of when that system is to be installed.

As the hull block was being constructed, the required manufactured

components were being fabricated in the shops using the appropriate system drawings for details. This opened up the idea of accomplishing outfit component manufacture simultaneous with and independent from structural fabrication.

Space was provided in the structural shop to place the deckhouse for outfitting and on-site material laydown during the on-block phase. In order to coordinate hanger locations, the trades used a "put-up/take-down" technique to install hangers so that all welding could be completed and clear access provided for thermal insulation application. The deckhouse was then ready for installation of the components to proceed according to the sequence developed.

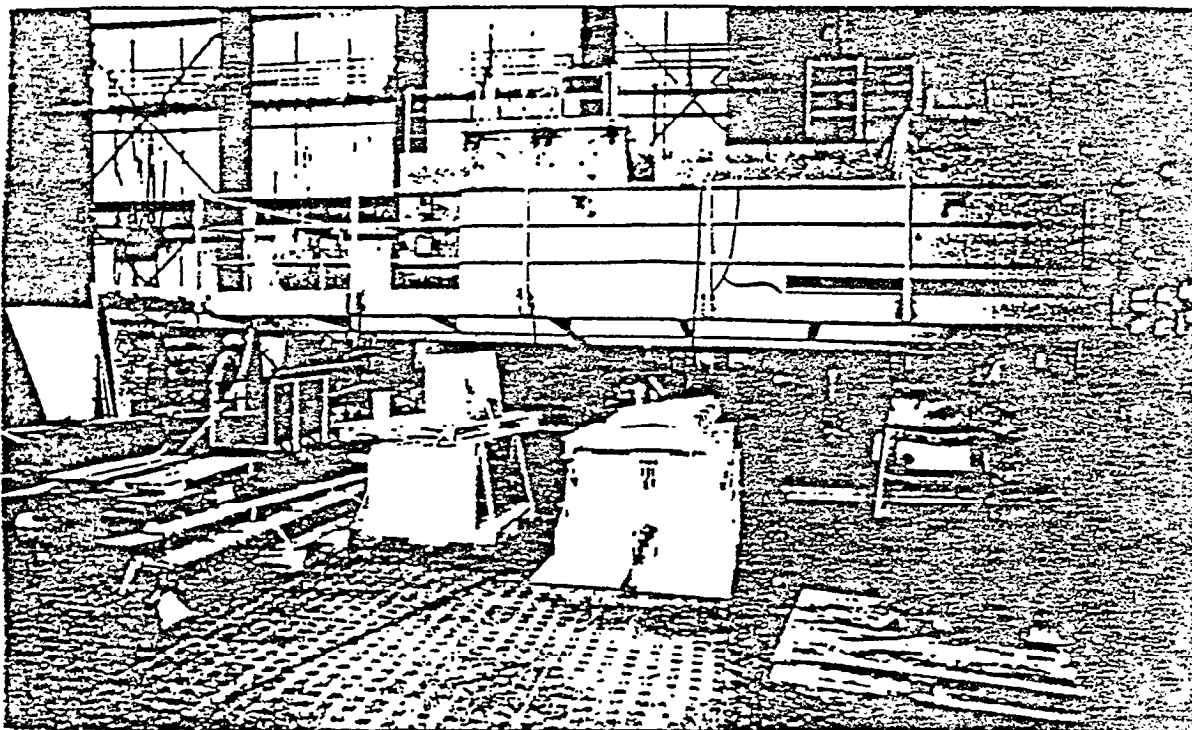


Figure 7
On-block outfitting of USS Ranger close-in weapon system deckhouse.
Components staged and accessible to trades.

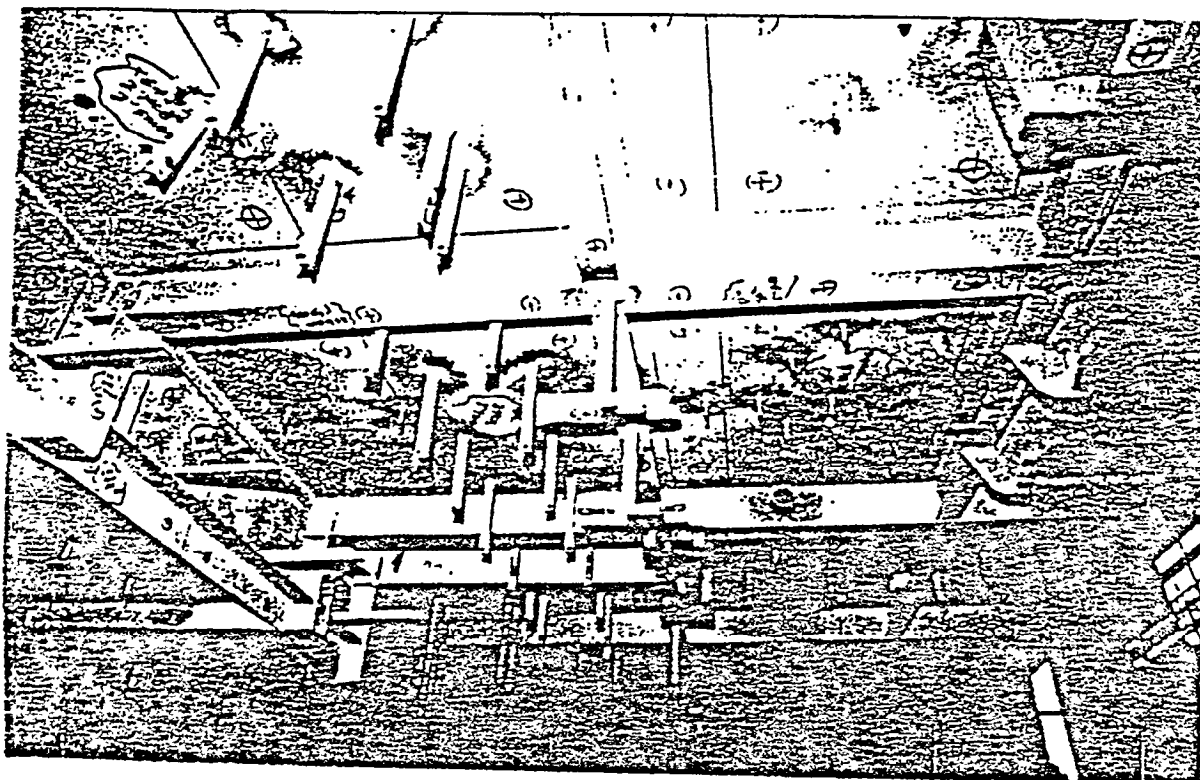


Figure 8
Hangers, brackets, and foundations located and installed.
Structure accessible for insulation application.

It should be noted that the deckhouse outfitting was 50 percent complete prior to ship arrival. This illustrates the impact that outfit planning can have on overhaul durations. One major factor that precludes complete outfitting of a new structure away from the ship is the allowance necessary for attachment to the existing structure. For the CV 61 deckhouse, a 24" strip around the attachment plane was left empty to allow clearance for welding when the house was attached to the ship.

At the ship's arrival the site preparation phase was accomplished in which the existing surface was cleared of interferences and prepared for accepting the new structure. To support the concept of accomplishing as much work in the shop as possible, photogrammetry was used to define the contour of the prepared island enclosure bulkhead. The data from the computer readout was transferred to the mating edge of the new deckhouse which allowed the structure to be trimmed while still in the shop.

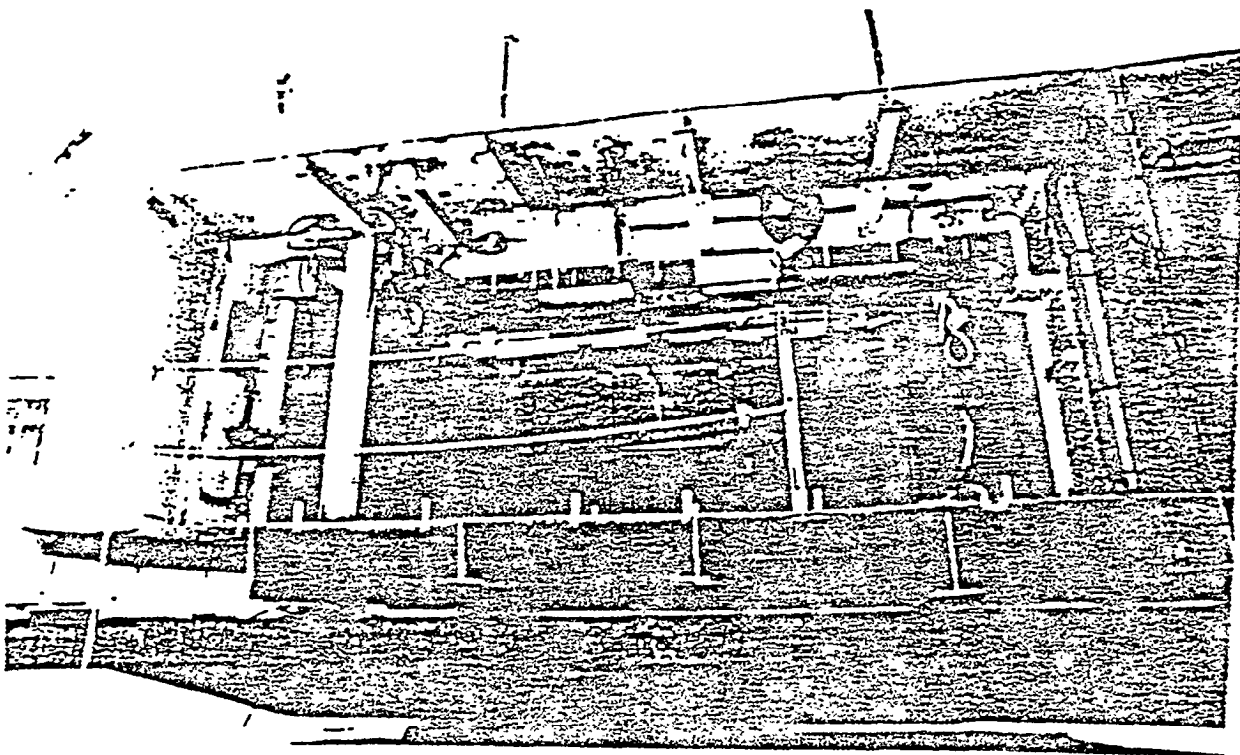


Figure 9

USS Ranger deckhouse transferred to site with outfitting 80 percent complete and mating edge trimmed. A 24" strip around the mating edge is left clear to facilitate site installation hot work.

Forty-four days after the ship's arrival, the new deckhouse, with 80 percent of the outfitting components installed, was attached to the existing ship. The fit-up interface between the new and existing structures averaged $\pm 1/16"$ which allowed production welding to begin within hours after the initial lift, and tied up pierside cranes for only four hours.

After the structure was welded in place, the remaining outfitting components were installed and interfaced with systems transiting the zone boundary.

Zone 2: Electrical Shop Upgrade

This project involved the complete reoutfitting of the existing Electric Shop with updated equipment to improve shipboard electrical repair capability. The shop is located on the third deck at centerline and represented the more typical type of overhaul work encountered by a repair facility. Interfacing of on-unit concepts with existing shipboard conditions provided the peculiar challenge of this project. It required the sequencing of nine different systems to be modified, and coordination of the affects of these on the existing systems.

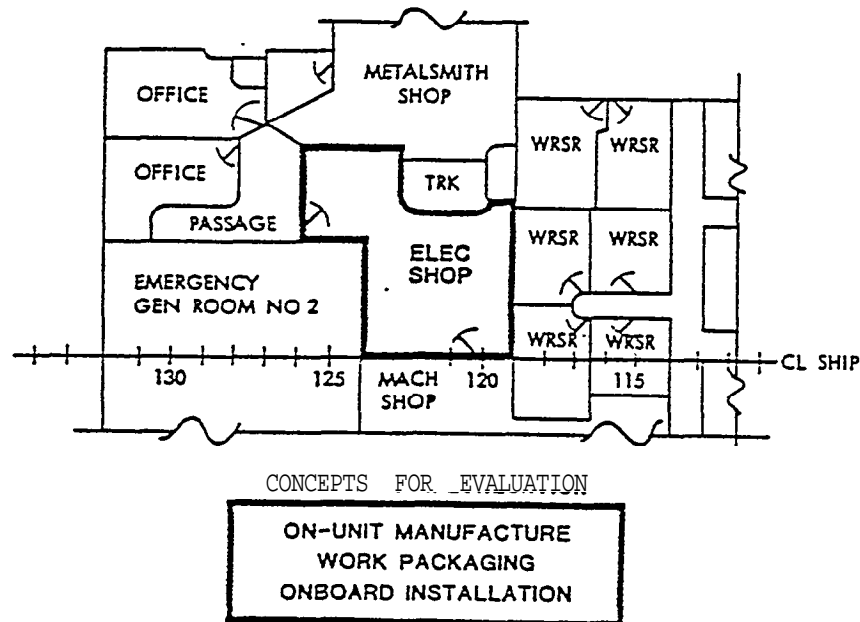


Figure 10
USS Ranger Electric Shop

With' this project, the composite drawing was used to identify the inter-relationship between the new components being installed, and the existing components being either removed, modified, or remaining. Preparation of the composite required extensive effort to correctly delineate the existing system location and configuration. With the aid of the composite, a number of system components that would have normally been fabricated and routed onboard were

designated for manufacture in the shop prior to the ship's arrival.

The concept of on-unit fabrication of the components was modified by permitting key piece trim allowance to accommodate final interface alignment with existing components. This procedure all owed for 90 percent of the particular run to be fabricated in the shop with the remaining 10 percent to be fitted onboard.

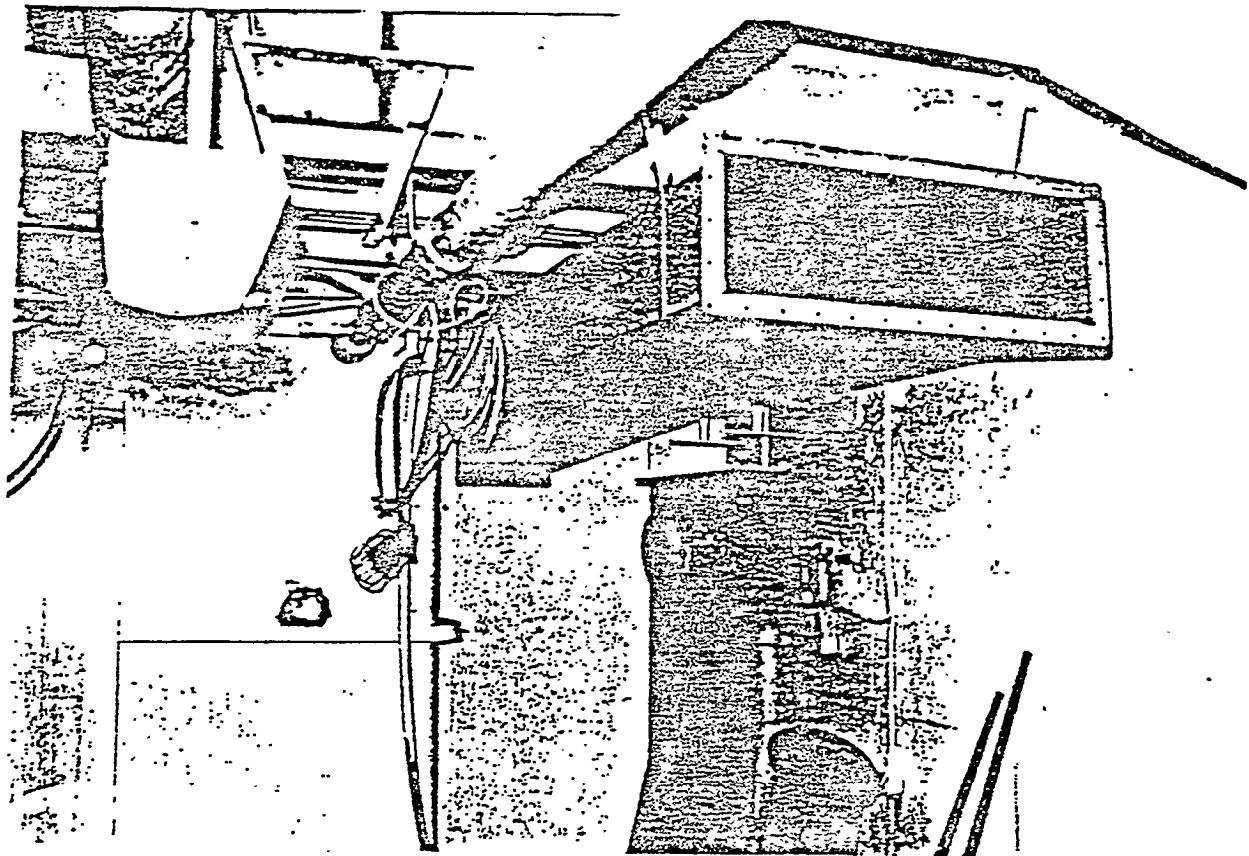


Figure 11
Integration of new components with existing systems
requires extensive coordination.

The Electric Shop task concentrated on the on-unit and onboard work concepts of zone logic and emphasized the trade coordination necessary to support the planned sequence of removal and installation. This task had a number of problems related to Government Furnished Equipment (GFE), but the 'shipyard was in a much better position to identify impact and coordinate solutions because it had a definite planned approach for the production effort.

CASE NO. 2: USS ARKANSAS (CGN 41)

A selected restricted availability for the cruiser USS Arkansas (CGN 41) provided an excellent opportunity for Puget Sound Naval Shipyard to expand on the outfit planning concepts initiated on USS Ranger. The planned availability is to be a short duration overhaul primarily for the purpose of installing Tomahawk weapon capability. This provided the opportunity to use the zone

logic application to a complete ship alteration and its affect on the entire ship.

Other variances from the Ranger task to be considered and evaluated are the use of systems drawings prepared by another design agent, and the use of computer aided design (CAD) to prepare the composite drawings. Incorporating these variances into the zone oriented planning process previously discussed represents a significant step forward for Puget Sound Naval Shipyard's application of outfit planning.

The Tomahawk project consisted of fabrication, outfitting, and installation of a 40'x12-1/2'x16' 40-ton equipment module below the main deck; installation of armored box launchers on the main deck; and, modification of various electronic control throughout the ship. This task profile offered the ability to expand on new construction and existing space modification techniques began on USS Ranger.

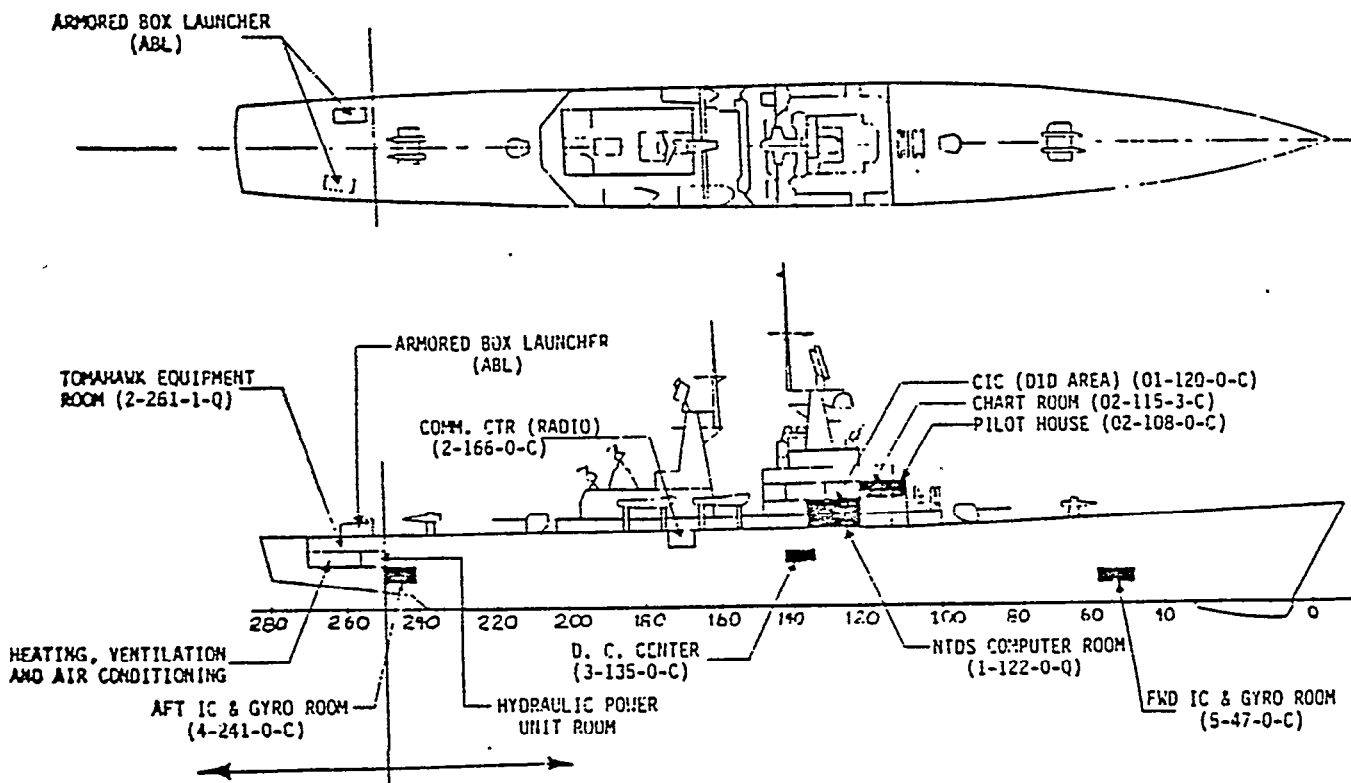


Figure 12
USS Arkansas Tomahawk Installation

Employing systems drawings prepared by design agents for use by other shipyards' production department is a situation that will be contended with more frequently in the future. The constraints of this condition on outfit planning application is a prime area of evaluation for the USS Arkansas project. Methods of introducing production input to these documents are being examined to allow timely response and substantial familiarity of the project for the installing activity. The Arkansas Outfit Planning Group was able to have some input to the structural prefabrication drawings, but drawing and production schedule compression precluded the Group's attempt to influence component systems drawings to provide a totally interrelated drawing package reflecting the build strategy.

The composite drawings used by the USS Ranger Outfit Planning Group were prepared by hand which was labor intensive and time consuming. In order to reduce cost and time for composite drawing preparation, the USS Arkansas Outfit Planning Group initiated the use of CAD for this effort. Not only was time reduced, but because of the "layering" capabilities of CAD, the flexibility of the composite drawing was greatly enhanced to allow view rotation, enlargement, and highlighting.

Based upon common work and schedule problems, the USS Arkansas Tomahawk project was divided into two zones. The first zone incorporates all work from the main deck down to the first platform at the aft end of the ship, which is comprised of the equipment module and launcher installation. The second zone was the interface with the remainder of the ship and focused on the electronic spaces being modified.

Fabrication, outfitting, and installation of the Tomahawk equipment module, Zone 1, once again offers opportunity to examine the complete on-unit, on-block, onboard outfitting cycle exemplifying new construction. The process of reviewing drawings and involving trade -- and technical personnel to determine a common build strategy resulting in the issue of a work package instruction, was continued. On-block outfitting of the module was completed, along with phase one and two testing, and ready for installation when the ship arrived. Other on-unit components were also completed and staged for installation. After shipboard site preparation is completed, the module and new outfitting components can be installed, tested, and turned over to the ship within the four-month time frame allotted.

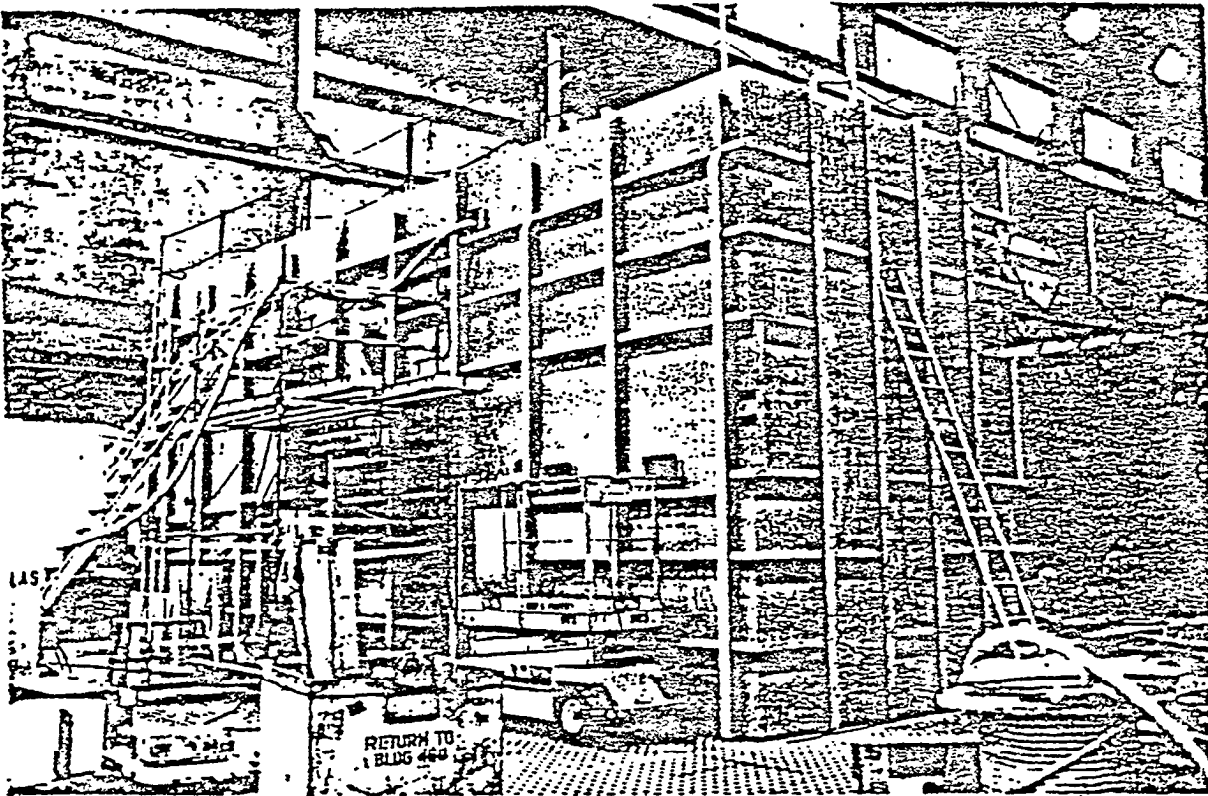


Figure 13
 USS Arkansas Tomahawk module in construction.
 Structural related outfitting requirements are incorporated.

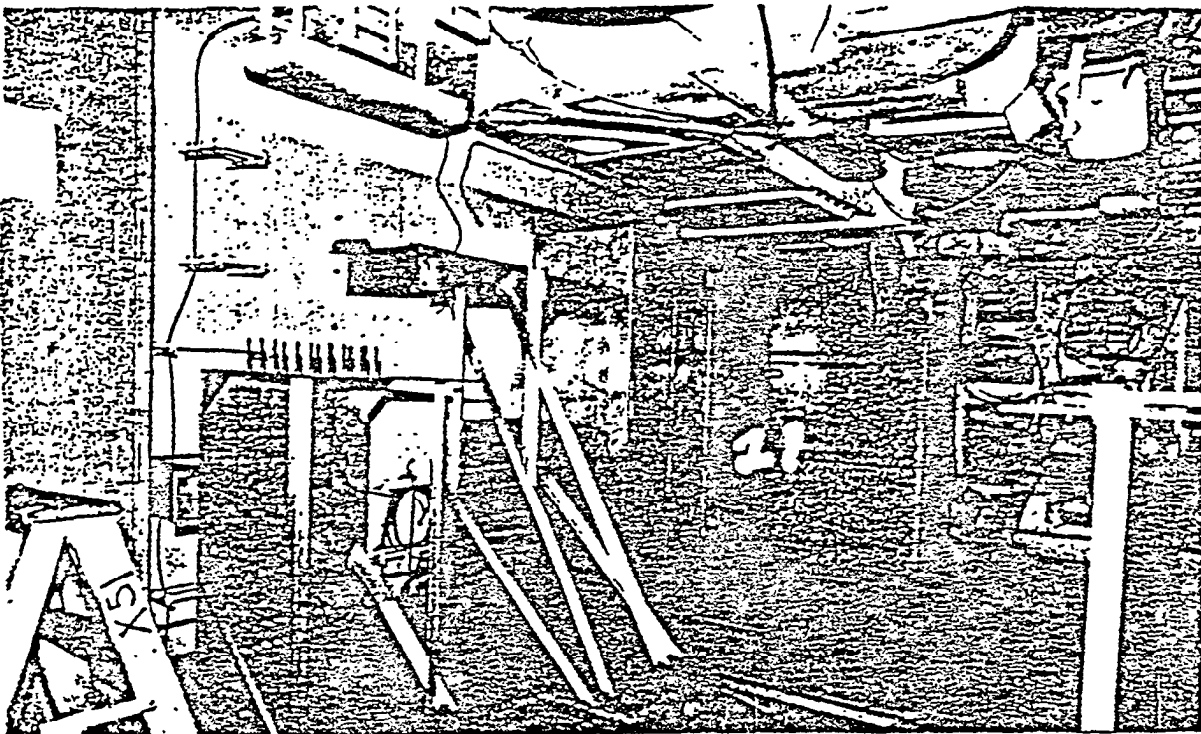


Figure 14
 On-block outfitting of USS Arkansas module allowed for equipment
 testing ready for installation at ship's arrival.

The "spread out" nature of Zone 2 is typical of overhaul/repair work normally accomplished by the shipyard. In order to deal with this situation, Zone 2 was divided into subzones to be able to concentrate on each compartment as separate but interrelated products. Since work in these dispersed compartments was limited to installation of peripheral electronic equipment to sup-

port the Tomahawk module, composites were not prepared for these subzones. The use of compartment cards was introduced as a method of packaging work for each of the compartments. These cards list all equipment and material requirements, material source or location, and sequencing information to be used in conjunction with the work package instruction.

13MB PSNS 4231/60 (Rev. 10-67)

COMPARTMENT MATERIAL SUMMARY CARD

CARD NO 01-120-0-C CGN 41		MEET 1 OF 3 USS ARYANSAS		COMPARTMENT NO 01-120-0-C AREA NO		DESCRIPTION COMBAT INFORMATION CENTER LOCATION 01-120-0-C			
ORG - WORK ORDER - MATERIAL DESCRIPTION		NAME PLATE	MATERIAL ORDERED		TYPE	Q-S NO	MATERIAL SOURCE	QTY.	MATERIAL STATUS
1 405-4735807/30041-72191-694									
2 OPERATOR INTERACTIVE DIS TERM					O.I.D.T.	EX9-MODO	GFE	5	
3 GRAPHICS CONTROL CENTER					HCU	EX7MODO	GFE	1	
4 CABLE -- ORDERED ON TOMAHAWK COMPUTER & EQUIP ROOM CARD									
5 401-4735811/30041-72191-678									
6 COOLING FAIL ALARM PANEL							RAYTHEON	1	
7 SWITCH SNAP 15R2C4A-2							RAYTHEON	2	
8									
9									
10 401-4735824/30041-72191-680									
11 ALARM SWITCHBOARD IC/SM-4							RAYTHEON	1	
12 INTRUSION ALARM RELAY PANEL							RAYTHEON	1	
13 RESISTOR 6.8K 1/2W							RAYTHEON	11	
14 DOOR OPER SWITCH TYPE S-193A							RAYTHEON	3	
15 NAMEPLATES						ALARM SWITCHBOARD	RAYTHEON	4	
16 CABLE DSGN-3						43143-00-131-476A	PSNS	15	
17 CABLE MSCU-7						426143-00-110-2302	PSNS	50	
18 CABLE TTSU-1 1/2						430143-00-110-2305	PSNS	130	
19									
20									
21 401-4735821/30041-72191-682									
22 SWITCHBOX 20CKT					A-19A	PSNS 6201-74091	JML 41231234	1	
23 SELECTOR SWITCH 16 POS					A-26A	1 -74295	41231235	4	
24 HANDSET							41231237	4	
25 TERMINAL BOX - 60 T							41231241	1	
26 HOLDER HANDSET						56201-74463	41231238	4	

Figure 15
Compartment card used to interface material requirements in various compartments.

CASE NO. 3: SUBMARINE TANK REPAIR

Repair of submarine tanks presents the opportunity to apply zone logic to a work process that usually does not involve installation of new equipment. The evolution of tank repair work during a typical submarine overhaul includes the opening, sandblasting or cleaning, painting, repair of damage, testing, and closing of as many as 50 tanks. The full extent of work necessary is not known until these tanks are available for inspection, which eliminates the use of the on-unit and on-block concepts of outfit planning. However, through the analysis of the typical repair cycle, identification and coordination of common onboard work processes can be accomplished.

By taking advantage of the input from production, design, planning and

estimating, supply, test engineering, and scheduling the sequencing of work achieved which provides for the proper resources being at the right place at the designated time. Through this group approach, the task resultant of sequencing tank repairs is:

- Identification of repairs early in the overhaul period
- Avoiding trade interference
- Minimizing rework
- Reducing duration of the tank repair process

It is being demonstrated that through the communication and cooperation of the Outfit Planning Group, the efficiency of the submarine tank repair process is improving and will culminate in a much improved standard approach which can be applied to any submarine.

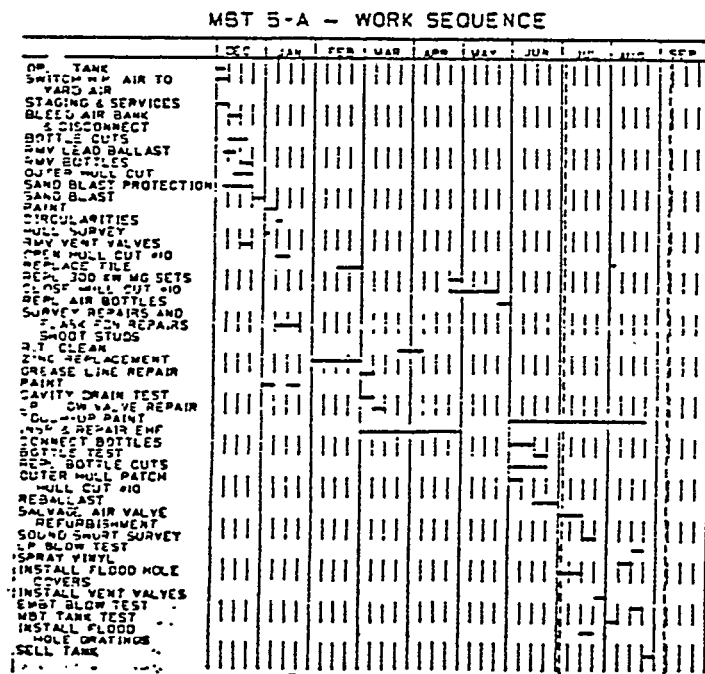


Figure 16
Bar chart used to coordinate work within submarine tank.
A similar bar chart sequences all tanks to be repaired.

CASE NO.4: USS LONG BEACH (CGN 9)

The selected restrictive availability of the cruiser USS Long Beach presented a new challenge to Puget Sound Naval Shipyard's outfit planning experiment. With less than two months between receipt of off-station prepared systems drawings and arrival of the ship to begin installation of Tomahawk systems, the Long Beach Outfit Planning Group was faced with developing an overhaul strategy within a very short time frame. Based on the experiences of the USS Ranger and USS Arkansas efforts, the Long Beach Outfitting Planning Group recognized that the shipyard was not yet ready to develop a full Tomahawk overhaul strategy within the extremely limited preplanning window given. However, with the attitude that zone logic could be still applied, even if only to a small portion of the project, the results would be of beneficial.

The group's efforts quickly focused on the crew living area directly below the Tomahawk launcher locations. Because of considerable structural changes required to support the launchers, all of the systems mounted to the overhead needed to be either replaced or modified. Because of the heavy congestion in this area, a composite was prepared by the design agent to aid the design effort.

In order to provide a viable sequence of onboard work, the group enhanced the use of existing composite drawings by the following process.

- Developed a structural panel drawing (SPD) depicting the new structural configuration of the crew living space overhead at 1 -1/2" = 1'-0" scale.
- Gave a reproducible copy of the SPD to each trade that had work to accomplish in this area, to delineate their particular system on the drawing based on

systems drawing provided. The trades also identified their prefabrication requirements.

The marked SPD's were collected and combined into a single overlay composite to accurately resolve interferences. Zone logic was used to identify construction and installation advantages.

- The resolved composite was then used by all trades to coordinate hanger locations, which allowed the hangers to be installed without having system components available.

With the installation sequence thus developed and agreed to, the composite became the tool by which the zone manager could control the outfitting installation onboard.

CASE NO. 5: USS TEXAS (CGN 39)

The complex overhaul of the cruiser USS Texas is furnishing the shipyards outfit planning experiment with the opportunity to expand the work package instruction process into a zone prefab work package related to a master bill of erection sequence. Building on the experiences of the previous outfit planning projects, the Texas Outfit Planning Group is making significant inroads on the way technical information is to be given to production personnel.

This project involves the installation of Tomahawk missile capability similar in scope, but different in detail from the USS Arkansas project. Attention is being placed on the prefabrication and outfitting of 46'x20'x19' 125-ton magazine/launcher module, and reconfiguration of two electronic control rooms. The electronic control room portion is designated as Zone 2, and will use a compartment card and composite drawing

combination to provide the basic tools for work analysis, sequencing, and instruction. The procedures used will be similar to those previously discussed as enhanced by the appropriate findings of the following process.

Major emphasis for the USS Texas project is on the magazine/launcher module, Zone 1, to deliver a more comprehensive work instruction to the mechanic in the form of a zone prefab work *package. This document will consist of numerous individual work instructions prepared from a complete CAD model of the module being built using a sequenced panel method.

The CAD model is being developed from system drawings provided by another design agent, and by using the layering capability of the CAD, each identified system is easily accessible individually or collectively. Systems input into the layered CAD files is being accomplished through a joint effort between design and production personnel. Where system rerouting may take advantage of using common hangers or improve manufacturing methods, hand layouts are being prepared by design personnel for review by the Outfit Planning Group. Once the

rerouting is firm, production personnel will locate the required hangers. This new data is then entered into the CAD to form an optimized CAD composite from which the graphic portion of the work instruction is developed.

The work package instruction is being enhanced by relating work to a sequenced panel erection process whereby each structural surface that makes up the zone is individually developed to reflect not only the structural members but also the outfitting components. These components are further identified as prefabricated pieces and tracked through the ordering, fabrication, and installation processes. With each piece being identified and tracked, control of the erection sequence is more manageable. This method provides for tracking of a piece from the original drawing, to locating the material required, where it is staged, when it is to be fabricated, which panel it is a part of, when it is to be installed, and how it is to be sequenced into the overhaul strategy. The work instructions are scheduled and sequenced in the zone prefab work package to reflect similar work processes and common manufacturing methods.

CONCLUSION

Adoption of zone logic concepts, developed for new construction projects, into the naval ship overhaul/repair process is continually proving its benefits. Unlike new construction, overhaul/repair work adds the necessity of dealing with existing entities that must be accounted for when planning new work. This results in gathering definitive data reflecting existing conditions installed by traditional system by system thinking, and integrating into it new work planned with zone logic concepts. Because of this added complexity factor and the potential organizational impact of zone logic, it was determined that an evolutionary process of small projects would best serve Puget Sound Naval Shipyard's venture.

The key factor to the continuing success of outfit planning at the shipyard is the establishment of interdepartmental groups to examine, develop, apply, and evaluate zone logic concepts for the various overhaul projects. By concentrating knowledgeable shipyard resources into one group and providing the forum for departmental interaction, levels of mutual respect and trust are reached which allows the channels of communication to open, and helps all members to understand how each is interfaced in the total ship overhaul process.

A large portion of the outfit planning projects have been aimed at prefabrication and outfitting of large modules being added to the ships. These types of projects represent a small portion of a normal ship overhaul while the majority of overhaul/repair work takes place within the existing hull. These hull modules have been emphasized during these early stages of the outfit planning experiment because they represent a common link between new construction and overhaul of existing ships, which provides the opportunity to become

familiar with zone logic ideas. However, because of the mix of projects undertaken thus far, it is evident that the majority of future routine overhaul/repair work will concentrate on the coordinated sequence of on-unit and on-board outfitting concepts.

By taking advantage of applying the shipyard's knowledgeable resources to analyzing work requirements, developing an overhaul strategy, and accomplishing as much work as possible before the ship arrives, a number of actual and potential benefits are being realized.

- Identifying and coordinating common trade requirements to reduce or eliminate accomplishing similar work in the same area at different times.
- Performing component fabrication and assembly under better, safer conditions in the shop rather than onboard the ship where competition for space hinders productive efforts.
- Work sequencing coordination which minimizes rework.
- Dedicated material staging areas and tracking methods to have components available when and where they are needed.
- Introduction of advanced technology procedures such as the use of photogrammetry and computer aided design.

Perhaps the most significant benefits realized are the involvement of the Production Department during the planning phase, and the development of the work package instruction. By participating in planning shipchecks and interacting with design personnel, the Production Department gains an improved understanding of the overall task requirements. Through this process the

Planning Department can provide improved instructions to support production methods. This interaction promotes a technical /trade teamwork approach to resolving problems on an equal basis.

In its development from the USS Ranger project to the USS Texas project, the work package instruction has become a powerful tool in using zone logic. The work package has evolved into a document that not only stands alone for the mechanic to accomplish his work but it has become the tool by which other related shipyard functions can be tracked. Items such as, manning, scheduling, material, budget, progressing, historical data, and quality assurance can now have a common

vehicle through which overhaul projects can be managed to reflect actual work requirements.

Puget Sound Naval Shipyard's experiences with outfit planning have both been positive and progressive. The change in thinking of identifying and accomplishing work by application of zone logic has met resistance with those who have "grown up" with the traditional systems approach; however, as each project has progressed, response has become much more favorable as the benefits are recognized. Step by step, as more people accept and participate in this logic change, more ideas are being injected to improve the shipyard's method of doing business.

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